Herring Stock Estimate from a Diving Survey of Spawn in Barkley Sound in 1982, with Comparisons to other Estimates

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HERRING STOCK ESTIMATE FROM A DIVING SURVEY OF SPAWN IN BARKLEY SOUND IN 1982, WITH COMPARISONS TO OTHER ESTIMATES

by

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ABSTRACT

Haegele, C. W. and J. F. Schweigert. 1984. Herring stock estimate from a diving survey of spawn in Barkley Sound in 1982, with comparisons to other estimates. Can. MS Rep. Fish. Aquat. Sci. 1798: 33 p.

Divers surveyed and sampled herring spawns in Barkley Sound on the west coast of Vancouver Island, B.C. in 1982 to determine the distribution of spawn and to estimate the biomass of herring and compare the results to other estimates. Although spawn was deposited to 14 m below Chart Datum, only 10% of spawn was lower than 4 m below Chart Datum. The diving survey estimated 23,500 tonnes of herring in Barkley Sound, of which 14,300 tonnes spawned in a first wave, 5500 tonnes spawned in a second wave, and 3600 tonnes were caught in fisheries between the two waves. Estimates from population models ranged from 7352 to 25,838 tonnes, depending on which assumptions were used. Generally they underestimated stocks, probably because Fishery Officer spawn survey data, used in all the models, considerably underestimated the area of spawn. Hydroacoustic estimates of biomass were slightly lower and echosounder estimates missed completely the build-up of stocks prior to spawning.

Key words: Pacific herring, spawn, diver survey, stock assessment

RÉSUMÉ

Haegele, C. W. and J. F. Schweigert. 1984. Herring stock estimate from a diving survey of spawn in Barkley Sound in 1982, with comparisons to other estimates. Can. MS Rep. Fish. Aquat. Sci. 1978: 33 p.

En 1982, des plongeurs autonomes ont étudié et échantillonné les stocks reproducteurs de hareng dans la baie Barkley, sur la côte ouest de l'île Vancouver (C.-B.), afin d'en déterminer la répartition et d'estimer la biomasse de hareng pour comparer les résultats à d'autres estimations. Quoique le frai ait été déposé jusqu'à 14 m au-dessous du zéro des cartes, seul 10% était présent à plus de 4 m au-dessous de cette valeur. Selon les résultats du levé, 23,500 t de hareng se trouvait dans la baie Barkley: 14,300 t ont fait partie d'une première fraie, 5500 t, d'une seconde, et 3600 t ont été pêchées entre les deux. Les estimations générées par des modèles démographiques variaient de 7352 à 25,838 t, selon l'hypothèse utilisée. En général, ces modèles ont sous-évalué les stocks probablement parce que les données sur la fraie recueillies par des agents des pêches et utilisées dans tous les modèles, sous-estimaient considérablement l'aire de fraie. Des estimations hydroacoustiques de la biomasse étaient légèrement plus basses, tandis que des levés par échosondeur ont entièrement manqué l'accumulaton de stocks avant la fraie.

Mots-clés: hareng du Pacifique, fraie, levé en plongée, évaluation des stocks

INTRODUCTION

Stock assessments for Pacific herring (Clupea harengus pallasi) in British Columbia have been made in a number of ways. The Hourston method, which evolved during the 1970s and was specifically developed for British Columbia herring, uses spawn survey data collected by Fishery Officers to calculate egg deposition and estimate spawner biomass (Hourston and Schweigert 1981). Since 1982 two population models, the age structured model and the surplus production model (Stocker et al. 1983), have been used to assess British Columbia herring stocks. Both of these models use spawn survey data collected by Fishery Officers. Stocks are also assessed on the fishing grounds prior to the roe fishery from echosounder estimates made from patrol vessels and charter test-fishery seine vessels (Chalmers 1982).

Stocks can also be assessed on the fishing grounds with more sophisticated hydroacoustic estimates of fish density and distribution (Taylor 1983). Alternately, the egg deposition is estimated by calculating the mean egg density from spawn samples collected by SCUBA divers and measuring the area of the spawn (Schweigert et al. 1984).

In 1982 a research project was conducted in Barkley Sound on the west coast of Vancouver Island (Fig. 1) to compare the results obtained from the traditional measures of stock abundance (Fishery Officers conducted echosounder estimates and spawn surveys) to estimates of biomass from hydroacoustic surveys and diving surveys of spawn. As well, herring were tagged in Barkley Sound prior to spawning and the fishery to determine stock movements in the sound and to make a mark-recapture estimate of stock abundance (Haegele et al. 1983).

The subject of this report is the stock estimate from the diving survey of spawn. This estimate is compared to the other estimates.

METHODS

Herring spawns were sampled by SCUBA divers using a two-stage sampling design (Schweigert et al. 1984). Transects perpendicular to the shore were the primary sampling unit and 0.50 m^2 quadrats sampled along the transect were the secondary sampling unit. Samples consisted of all the rooted or attached vegetation, and the eggs adhering to it, within the quadrat. These samples, after collection, were separated by vegetation classes (Haegele et al. 1979) into fractions, which were then weighed. A weighed subsample of each fraction was preserved for subsequent egg enumeration. Eggs on the bottom substrate were estimated from diver estimates on layers of eggs and percent of bottom covered by eggs [1 layer of eggs = $3.40 \cdot 10^5$ eggs$\cdot m^{-2}$ (Haegele et al. 1979)] and added to eggs on vegetation. For

each quadrat the layers of eggs and the percent cover of vegetation were estimated by divers and the depth at each sample site was recorded and later corrected to Chart Datum from water levels observed at Tofino (Tides and Currents, Institute of Ocean Sciences, Sidney, B.C.).

Transects were established at approximately equal intervals and marked with gillnet leadline. Samples were collected also at equal intervals along transects. Based on the preliminary analysis of results from studies in the Strait of Georgia, the optimal level of sampling was a transect density of 2.5 transects$\cdot km^{-1}$ and 5 samples per transect. In this survey, transect density was 2.6 transects$\cdot km^{-1}$ for Barkley Sound. However shorter spawns were sampled at a higher intensity of up to 6.3 transects$\cdot km^{-1}$, and longer spawns at a lower intensity, as low as 1.7 transects$\cdot km^{-1}$. Samples were generally taken at 20 m intervals. For spawns narrower than 100 m samples were taken every 10 m, and for spawns narrower than 50 m samples were taken every 5 m. The average number of samples per transect in this survey was 6.8 (n=69, SD-3.3). The mean egg density (eggs$\cdot m^{-2}$) and 95% confidence interval were calculated assuming unequal primary units (transect lengths). This estimator weights the within transect means by the transect length to determine an overall mean for the spawn (Schweigert et al. 1984).

The inner and outer edge of spawns were determined from measurements along transects and the end of spawns beyond the outer transects were determined on exploratory dives. This information and the depth at sample sites were plotted on maps of shoreline vegetation at a scale of 1:4800 (Haegele and Hamey 1980). The boundaries of the spawn and 2 m depth intervals were contoured using this information. The area of spawn between the 2 m depth contours was measured using an Apple graphics tablet . Spawner biomass (tonnes) was estimated as the product of spawn area, egg density and 10^{-8}, which assumes 200 eggs$\cdot g^{-1}$ female weight (Hay 1985) and a 1:1 sex ratio. Egg distribution by 2 m depth interval was estimated as the product of spawn area and mean eggs$\cdot m^{-2}$ of samples obtained within the depth stratum.

Fishery Officers assessed the spawns independently from divers, recording length, average width, and average layers of eggs (Chalmers 1982). Stocks were assessed with three population models (Stocker et al. 1983). An echosounder estimate was made from the charter seine vessel PACIFIC HARVESTER and the Fisheries Patrol vessel COMOX POST and the hydroacoustic survey was made from the charter seine/trawl vessel EASTWARD HO (Taylor 1983). Herring were tagged from sets made by the PACIFIC HARVESTER between February 20 and March 7, 1982 (Haegele et al. 1983).

RESULTS AND DISCUSSION

DIVING SURVEY OF SPAWN

Herring spawned in two major waves in Barkley Sound in 1982. All the spawns of the first wave (March 8-10) were surveyed by divers. Not all

the spawns of the second wave were surveyed by divers. The spawn in Toquart Bay (March 23-25) was surveyed, spawns from Mayne Bay to Dutch Harbour (March 24-30) and in Spring Cove (March 22-23) were not surveyed by divers because the field camp (the research barge VELELLA) was moved from Barkley Sound on March 30. However, divers conducted exploratory dives on the Mayne Bay to Dutch Harbour spawn to visually assess length, average width and egg layers.

We are reasonably certain that for spawns surveyed by divers, all of the spawn was located and sampled. Unless there was egg loss between egg deposition and the time of the survey, and there was only a minor and not very clear trend for egg density to decrease with time between spawning and survey (Table 1), then our estimate should be a reliable and only slightly conservative estimate of spawner biomass. For the combined data, 95% confidence limits for egg density were within 25% of the mean ($x=4.592 \cdot 10^5$ eggs$\cdot m^{-2}$, 95% C.I. of $3.427 \cdot 10^5$ to $5.757 \cdot 10^5$ eggs$\cdot m^{-2}$). For individual spawns the confidence limits were broader (Table 2).

Biomass estimates

Divers delineated and sampled 9 spawns (Figs. 2-7; Table 2). The Maggie River and Larkins Island spawns (Fig. 3) had low egg density and were deposited by 296 and 100 tonnes of spawners, respectively. The spawns around the Ottaway Group (Spilling, Rowlands and Ottaway islets), St. Ines and David islands (Fig. 4) had moderate to heavy egg density and were deposited by 1044, 941, and 1588 tonnes of spawners, respectively. The spawn on Forbes Island (Fig. 5) was of moderate egg density and was deposited by 863 tonnes. The spawn in Macoah Passage, from Maggie River to beyond Twin Rivers (Figs 5, 6) was also of moderate egg density and was deposited by 7823 tonnes of spawners. The spawn at the entrance to Ucluelet Inlet (Fig. 7) was of low egg density and was deposited by 194 tonnes of spawners. Together, these spawns of the first wave were deposited by 14,322 tonnes of herring. The analysis for the total treats all spawns of the first wave as one spawn, hence the total is not the sum of the individual spawns (sum is 12,849 tonnes). The Toquart Bay spawn (Fig. 2), the only second wave spawn sampled by divers, was deposited by 2793 tonnes. Additionally, it was estimated from visual observations that spawns from Mayne Bay to Dutch Harbour and in Spring Cove were deposited by 2671 and 62 tonnes respectively. The second wave spawn was estimated to have been deposited by 5525 tonnes. For the second wave, the total spawner biomass is the same as the sum for individual spawns because the egg density from the Toquart Bay spawn was used throughout. Visual observations indicated that egg density in the two spawns not sampled were similar to egg densities in Toquart Bay. The best estimate for all of Barkley Sound, treating all the spawns as one spawn, is 19,882 tonnes of spawners. The sum for the 9 individual spawns is 18,375 tonnes. The estimate of the 1982 catch in Barkley Sound is 3613 tonnes (Stocker et al. 1983). Hence, the total Barkley Sound stock was estimated at 23,495 tonnes.

Spawn distribution

The Vancouver Island shoreline from Toquart River to the entrance to Ucluelet Inlet was found to have a more gradual slope than the shoreline at the head of Toquart Bay and on the islands where spawn was found. Also, along the Vancouver Island shoreline spawn was not found deeper than 6 m below Chart Datum while on the islands spawn was found to 14 m below Chart Datum (Table 2). Mean percent cover of vegetation, mean layers of eggs and mean egg density ($egg \cdot m^{-2}$) were calculated for each 2 m depth interval (Fig 8). This analysis showed that percent cover of vegetation was not significantly different between "Vancouver Island shoreline" and "islands" spawns but that layers of eggs and egg density were significantly higher for "islands" spawns than for "Vancouver Island shoreline" spawns in the two most shallow depth intervals. Percent cover of vegetation decreased with depth for both shorelines. Layers of eggs and egg density ($eggs \cdot m^{-2}$) first increased with depth for "Vancouver Island shoreline" spawns, while for "islands" spawns layers of eggs and egg density decreased with depth. However, mean values between adjacent depth intervals were infrequently significantly different. Since there were significant differences in egg density between "Vancouver Island shoreline" and "islands" spawns at some of the same depth intervals, calculations of eggs by depth were done separately (Table 4) and then summed to show the total distribution of spawn by depth (Fig. 9). This analysis showed that 70% of the spawn, by area and by the number of eggs, was deposited below 0.0 m Chart Datum and that approximately 10% of the spawn was deposited lower than 4 m below Chart Datum. This spawn distribution is similar to that in the Strait of Georgia where, depending on the transect slope and vegetation, 15 to 95% of the eggs were found below 0 m Chart Datum and 0 to 20% of the eggs were found lower than 4 m below Chart Datum (Haegele et al. 1981).

FISHERY OFFICER SURVEY OF SPAWN

Fishery Officers located and surveyed most of the spawn found by divers, the only exception being the spawn on Snowden Island (transects B18, 19 in Toquart Bay) (Fig. 2). Fishery Officers reported on longer spawns in several patches. The results of the Fishery Officer spawn survey are compared to results from the diving survey in Table 5. Spawn lengths were moderately underestimated, area of spawn was considerably underestimated, and layers of eggs were generally overestimated by Fishery Officers relative to the diving survey results. Fishery Officers reported about 7% of the area for the nine spawns surveyed by divers. It would appear that they saw only the spawn deposited higher than about 1.5 m above Chart Datum (Fig. 9). The mean tide level during daylight hours of March 12 and 25, when Fishery Officers surveyed the 9 spawns surveyed by divers, was 2.3 m above Chart Datum. Hence, it appears that they only reported on the spawn that was either exposed or in very shallow water at the time of the survey. Unquestionably the techniques employed of necessity by Fishery Officers, visual inspection from the water surface and grappling, are the reason for underestimates of spawn area.

Furthermore, Fishery Officers conducted their major survey in only 2 days, although they were present on the grounds for most of March, while the diving survey was conducted in 13 days over a 3-week survey period.

POPULATION MODEL STOCK ESTIMATES

The Hourston method of stock assessment calculates egg deposition from Fishery Officer spawn survey results. For Barkley Sound a 0.33 "egg survival factor" is used to compensate for under-reporting of spawn. Using this factor, the Hourston method estimate for Barkley Sound was 7055 tonnes of spawners (Stocker et al. 1983). A factor of 0.12 would have to be used to produce an estimate of 19,882 tonnes, the estimate from the diving survey. This factor is higher than the 0.07 factor by which area was underestimated by Fishery Officers because estimates of layers of eggs by Fishery Officers were higher than by divers, resulting in higher egg density (eggs$\cdot m^{-2}$) than that obtained in the diving survey.

The stock estimates from the diving survey cannot be directly compared to stock estimates from the age-structured and surplus production models since these model stock assessments were made for the west coast of Vancouver Island as a whole. According to the Hourston method, 0.28 of west coast of Vancouver Island stocks spawned or were fished in Barkley Sound. If this ratio is applied to the models then the estimate from the age-structured model with the constant assumption (22,225 tonnes) and the estimate from the surplus production model with the q=0.003 assumption (17,858 tonnes) for spawner biomass were closest to the diving survey estimate of 19,882 tonnes (Table 6). All other assumptions produced considerably lower stock estimates.

HYDROACOUSTIC, ECHOSOUNDER AND TAGGING ESTIMATES OF BIOMASS

The hydroacoustic estimate for fish in Barkley Sound up to March 6 was for 14,308 tonnes (Taylor 1983). The diving survey estimate for the first wave of spawners was for 14,322 tonnes. However, according to tag recoveries (Haegele et al. 1983) fish that were included in the hydroacoustic estimate consisted of a mixture of first wave spawners, second wave spawners (some of which were caught in the fishery), and fish that left the sound to spawn elsewhere (Table 11). Tag density in the catch decreased three-fold in Barkley Sound between March 13 and March 18, which would support the theory that additional stocks were moving into the sound to spawn in the second wave. However, probably 30% of the second wave spawners and catch were in the sound at the time of the tagging (February 20 to March 7) and at the time of the hydroacoustic estimates (February 18 to March 12). It can be assumed that all of the first wave spawners were in the sound at the time of the hydroacoustic survey and tagging and that 10% of the fish in the sound left to spawn elsewhere. Applying these assumptions there were 14,322 tonnes of first

wave spawners (diving survey estimate), 1842 tonnes of second wave spawners (30% of diving survey estimate), 1204 tonnes of catch (30% of Barkley Sound catch), and 1929 tonnes of other west coast of Vancouver Island stocks (10% of total) in the sound at the time of the hydroacoustic survey for a total of 19,307 tonnes.

Using these same assumptions only 2818 of the 17,860 tagged fish remained in the sound at the time of the 3613 tonnes permit and seine fisheries of March 13, 17 and 18. An adjusted Peterson mark-recapture estimate (Ricker 1975), assuming 10% tagging mortality, of fish in Barkley Sound at the time of tagging is for 17,555 tonnes (95% C.I. of 16,149 to 19,170 tonnes)[1]. Since the assumption was that 3683 tonnes of the second wave spawners moved into the sound after tagging, the total for Barkley Sound spawners using the mark-recapture estimate is 21,278 tonnes, only slightly higher than the 19,882 tonnes diving survey estimate. Hence, the assumptions about stock movements in the sound appear to be realistic and the hydroacoustic estimate was for 74% of actual biomass present (14,308 tonnes vs 19,307 tonnes). This is expected since some of the fish would have been in waters among the islands of the Broken Group, an area which was not covered by the hydroacoustic survey, as they moved from Imperial Eagle Channel to the northwest side of Barkley Sound.

The echosounder estimate made by the Fishery Officers never showed more than 5440 tonnes present in Barkley Sound. Taylor (1983) compares echosounder to hydroacoustic estimates on a daily and area basis and concludes that echosounder estimates missed completely the build-up of stocks prior to the first wave spawning and generally underestimated biomass throughout the survey period.

SUMMARY

1. The estimate, from diving surveys of spawn, of Barkley Sound herring biomass in 1982 is 23,500 tonnes, of which 14,350 tonnes spawned in a first wave between March 8 and 10, 5550 tonnes spawned in a second wave between March 22 and 30, and 3600 tonnes were caught in fisheries on March 13, 17, and 18.

2. Herring spawn was deposited between 2 m above Chart Datum and 14 m below Chart Datum with 70% of the spawn below 0 m Chart Datum and 10% lower than 4 m below Chart Datum.

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[1]Values for the adjusted Peterson mark-recapture estimate are M=2536 tags, R=520 tags, C=3613 tonnes, N=17,595 tonnes, SD=771 tonnes, R_1=567 tags, R_2=477 tags, N_1=16,149 tonnes, and N_2=19,170 tonnes.

3. Fishery Officers, in their spawn surveys, moderately underestimated the length of spawn, considerably underestimated the area of spawn, and moderately overestimated the layers of eggs, relative to the diving survey estimate.

4. Of the three population models, Hourston's method underestimated spawning stocks roughly by the degree the "egg survival factor" for Barkley Sound overestimated the proportion of spawn reported by Fishery Officers. The age-structured model and the surplus production model, depending on which assumptions are used, can estimate stocks at about the same size as the diving survey.

5. Hydroacoustic estimates were 25% lower than biomass estimated from the diving survey and tagging. Given the rapid and complex movement of stocks in the sound, it is likely that not all the fish were encountered during the daily hydroacoustic surveys. Hence, the hydroacoustic survey probably estimated closely all the fish that were present in the areas surveyed.

6. Echosounder estimates were much lower than hydroacoustic and diving survey estimates. The reason for this is unclear.

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Table 1. Mean egg density on vegetation (eggs·m^{-2}) by days elapsed between time of spawning and time of survey for "Vancouver Island shoreline" spawns, "islands" spawns, and all of Barkley Sound.

Days elapsed	Vancouver Island				Islands				Barkley Sound			
	No. of transects	No. of samples	Eggs·10^{-3}·m^{-2} Av.	SE	No. of transects	No. of samples	Eggs·10^{-3}·m^{-2} Av.	SE	No. of transects	No. of samples	Eggs·10^{-3}·m^{-2} Av.	SE
2	8	81	800	333	1	6	188	77	9	57	729	316
3	9	39	552	184	3	34	350	190	12	73	457	186
4	9	65	674	352	-	-	-	-	9	65	674	352
5	-	-	-	-	10	93	392	126	10	93	392	126
6	-	-	-	-	2	26	508	146	2	26	508	146
8	-	-	-	-	3	20	303	80	3	20	303	80
9	-	-	-	-	6	42	100	78	6	42	100	78
10	6	31	449	275	-	-	-	-	6	31	449	275
11	7	34	422	261	2	12	293	137	9	46	389	235
14	3	17	122	99	-	-	-	-	3	17	122	99

Table 2. Survey information and estimates of egg density and spawner biomass for 1982 herring spawns in Barkley Sound.

Time	Location	Length (km)	Area (ha)	No of transects	No of samples	Eggs $\cdot 10^{-3} \cdot m^{-2}$ (95%)	Tonnes of spawners (95%)
1st wave	Maggie River	3.5	28.16	6	40	105.0 (-1.4 to 211.4)	296 (0 to 595)
	Larkins Island	0.9	8.03	3	17	124.0 (1.9 to 246.2)	100 (2 to 198)
	Ottaway Group	1.6	22.37	7	34	466.5 (183.8 to 749.3)	1044 (411 to 1676)
	St Ines Island	1.8	14.89	7	48	631.8 (284.1 to 976.6)	941 (423 to 1459)
	David Island	0.8	13.56	5	34	1170.8 (541.4 to 1800.2)	1588 (734 to 2441)
	Forbes Island	2.0	18.57	6	31	464.7 (23.9 to 905.4)	863 (44 to 1681)
	Macoah Passage to Twin Rivers	9.0	191.49	15	139	408.5 (273.4 to 543.7)	7823 (5236 to 10,411)
	Ucluelet-Ent.	1.8	11.76	2	12	164.7 (-267.8 to 557.2)	194 (0 to 702)
All First Wave		21.4	308.83	51	355	463.8 (326.5 to 601.0)	14,322 (10,083 to 18,562)
2nd wave	Toquart Bay	5.0	62.75	18	113	445.1 (223.6 to 666.5)	2793 (1403 to 4182)
	Mayne Bay to Dutch Harbour	4.0 (est)	60.00 (est)	0	0	445.1 (est)	2671 (est)
	Spring Cove	0.8 (est)	1.39 (est)	0	0	445.1 (est)	62 (est)
All Second Wave		9.8	124.14	18	113	445.1 (223.6 to 666.5)	5525 (2776 to 8274)
All Barkley Sound		31.2	432.97	69	468	459.2 (342.7 to 575.7)	19,882 (14,838 to 24,926)

Table 3. Area of spawn (ha) by depth interval for individual spawns grouped by beach slope into gradual (Vancouver Island shoreline) and steep (islands) shorelines.

	Depth Interval (m above or below Chart Datum)								
Location	+2to0	0to-2	-2to-4	-4to-6	-6to-8	-8to-10	-10to-12	-12to-14	+2to-14
Vancouver Island shore									
Toquart River	34.00								34.00
Maggie River	18.50	9.66							28.16
Macoah Pass	43.17	101.51	41.70	5.11					191.49
Ucluelet Inlet	0.26	6.37	4.83	0.30					11.76
All	95.93	117.54	46.53	5.41					265.41
Islands									
Larkins Island	0.51	1.02	1.28	1.28	1.28	1.27	1.07	0.32	8.03
Ottaway Group	0.70	2.64	4.59	4.61	3.22	3.09	2.06	1.46	22.37
St. Ines Island	4.52	5.97	4.10	0.30					14.89
David Island	3.04	4.76	3.50	1.62	0.64				13.56
Forbes Island	4.36	3.94	2.48	2.47	2.00	1.65	1.10	0.57	18.57
Toquart Bay	6.78	6.37	4.68	3.98	3.71	2.12	0.81	0.30	28.75
All	19.91	24.70	20.63	14.26	10.85	8.13	5.04	2.65	106.17
Barkley Sound-Total	115.84	142.24	67.16	19.67	10.85	8.13	5.04	2.65	371.58

Table 4. Estimates of egg density and spawner biomass by depth interval (m above and below Chart Datum) for 1982 herring spawns in Barkley Sound surveyed by divers (spawns segregated by beach slope).

Location	Depth interval	Area (ha)	Eggs·10^{-3}·m^{-2} (95% C.I.)	Tonnes of spawners (95% C.I.)
Vancouver Is shore	+2 to 0	95.93	300.9 (194.0-407.9)	2887 (1861-3913)
	0 to -2	117.54	393.8 (284.2-503.5)	4629 (3340-5918)
	-2 to -4	46.53	384.7 (239.8-529.7)	1790 (1116-2465)
	-4 to -6	5.41	161.5 (52.7-270.2)	87 (29-146)
Islands & Toquart Bay	+2 to 0	19.91	936.2 (656.0-1216.4)	1864 (1306-2422)
	0 to -2	24.70	708.7 (488.5-928.9)	1751 (1207-2294)
	-2 to -4	20.63	491.1 (282.8-699.4)	1013 (583-1443)
	-4 to -6	14.26	307.2 (145.9-468.5)	438 (208-668)
	-6 to -8	10.85	533.7 (112.2-955.3)	579 (122-1037)
	-8 to -10	8.13	206.0 (24.9-387.2)	168 (20-315)
	-10 to -12	5.04	338.2 (7.3-669.2)	171 (4-337)
	below -12	2.65	132.0 (18.1-245.8)	35 (5-65)

Table 5. Comparison of diver survey and Fishery Officer survey results for 1982 herring spawns in Barkley Sound.

Location	Transects	Diver			Fishery Officer			F.O.-Div.$^{-1}$		
		Length (m)	Area (ha)	Layers	Length (m)	Area (ha)	Layers	Length	Area	Layers
Maggie River	B4-B6	1500	10.10	0.6	750	0.75	2.0	0.50	0.07	3.33
	B1-B3	2000	18.06	1.6	100	3.00	4.0	0.75	0.17	2.50
		3500	28.16	1.2	2250	3.75	3.6[a]	0.64	0.13	3.00
Larkins Island	B1-B3	850	8.03	0.8	200	0.10	2.0	0.22	0.01	2.50
Ottaway Group	B1-B4,B7	1200	11.94	2.2	600	0.60	4.0	0.67	0.05	1.82
	B5,B6	400	10.43	3.8	500	0.25	4.0	1.25	0.02	1.05
		1600	22.37	2.9	1100	0.85	4.0	0.79	0.04	1.38
St Ines Island	B0-B6	1800	14.89	3.0	1300	2.60	5.0	0.72	0.17	1.67
David Island	B1-B5	800	13.56	4.2	1000	1.50	4.2	1.25	0.11	1.00
Forbes Island	B1-B6	2000	18.57	3.5	1100	1.10	4.0	0.50	0.06	1.14
Macoah Passage	B1-B8,B9	3000	49.24	1.8	2400	4.80	2.8	0.80	0.10	1.53
and Twin Rivers	B1,B2	3500	95.75	2.0	2900	5.80	3.0	0.83	0.06	1.50
	B3-B5	2500	46.50	2.1	650	0.65	1.5	0.26	0.01	0.71
		9000	191.49	1.9	5950	11.25	2.8[a]	0.66	0.06	1.47
Ucluelet-Ent.	B1,B2	1800	11.76	1.3	350	0.18	2.0	0.35	0.02	1.54
Toquart Bay	B14-B17	800	9.50	3.0	750	0.75	2.0	0.94	0.08	0.67
	B12,B13	600	3.05	3.4	500	0.05	2.0	0.83	0.08	0.59
	B5,B7-B11	1500	7.80	2.2	1170	0.35	2.0	0.78	0.04	0.91
	B18,B19	700	8.40	2.2	-	-	-	-	-	-
	B1-B4	1400	34.00	1.6	600	0.60	2.0	0.43	0.02	1.25
		5000	62.75	2.2	3020	1.95	2.0	0.60	0.03	0.91
Mayne Bay to	None	-	-	-	700	0.70	4.0	-	-	-
Dutch Harbour	None	-	-	-	50	1.65	4.0	-	-	-
	None	-	-	-	2450	7.35	6.0	-	-	-
	None	-	-	-	600	0.18	4.0	-	-	-
		4000 (est)	60.00 (est)	2.0 (est)	4300	9.88	5.5[a]	-	-	-
Spring Cove	No survey	830 (est)	1.39 (est)	2.0 (est)	500	0.25	4.0	-	-	-
Barkley Sound		31,180	432.97	2.3	21,070	33.41	4.0[a]	0.68	0.08	1.74

[a]Layers weighted by reported area.

Table 6. Barkley Sound spawner biomass estimates from population models (from Stocker et al. 1983).

Model	Assumption	W.C.V.I. Stock (tonnes)	Barkley Sound Proportion	Barkley Sound Stock (tonnes)	Barkley Sound Spawners (tonnes)
Hourston	a	38,455	0.277	10,668	7055
Age-structured[b]	Constant[c]	93,138	0.277	25,838	22,225
	Variable[d]	62,092	0.277	17,225	13,612
Surplus production	q=0.003	77,397	0.277	21,471	17,858
	q=0.006	38,430	0.277	10,661	7,048
	q=0.009	26,500	0.277	7,352	3,739
	q=variable	28,395	0.277	7,877	4,264

[a]"Egg survival factor" is section specific with values of 0.33, 0.50, and 1.00 used.

[b]Assumes all 3-yr old and older fish are spawners.

[c]"Constant" assumes constant natural mortality and spawn index.

[d]"Variable" assumes density dependent natural mortality and time dependent spawn index.

Table 7. Recoveries (adjusted for gear and plant recovery rates) in 1982 roe fisheries from Barkley Sound taggings, catch, and tag density in catch.

Fishery	No. of recoveries	Catch (tonnes)	Tag density (tags·1000t^{-1})
Area 23 - Charter (Mar 13)	176	542	325
Area 23 - SN (Mar 17,18)	344	3071	112
Area 24 - SN & GN (Mar 8,9)	83	1538	54
Area 25 - GN (Mar 7-12)	9	1905	5

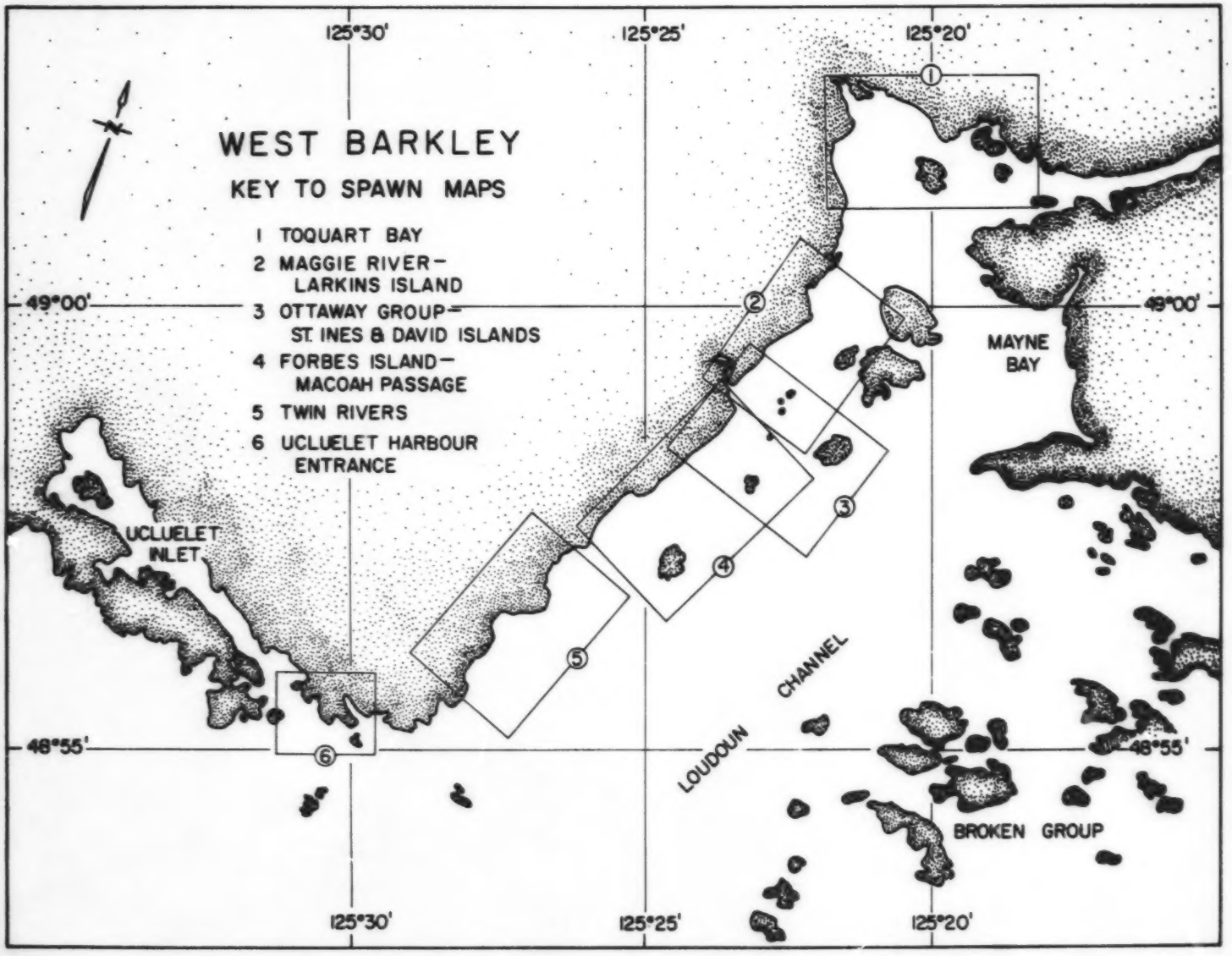

Figure 1. Map of Barkley Sound study area.

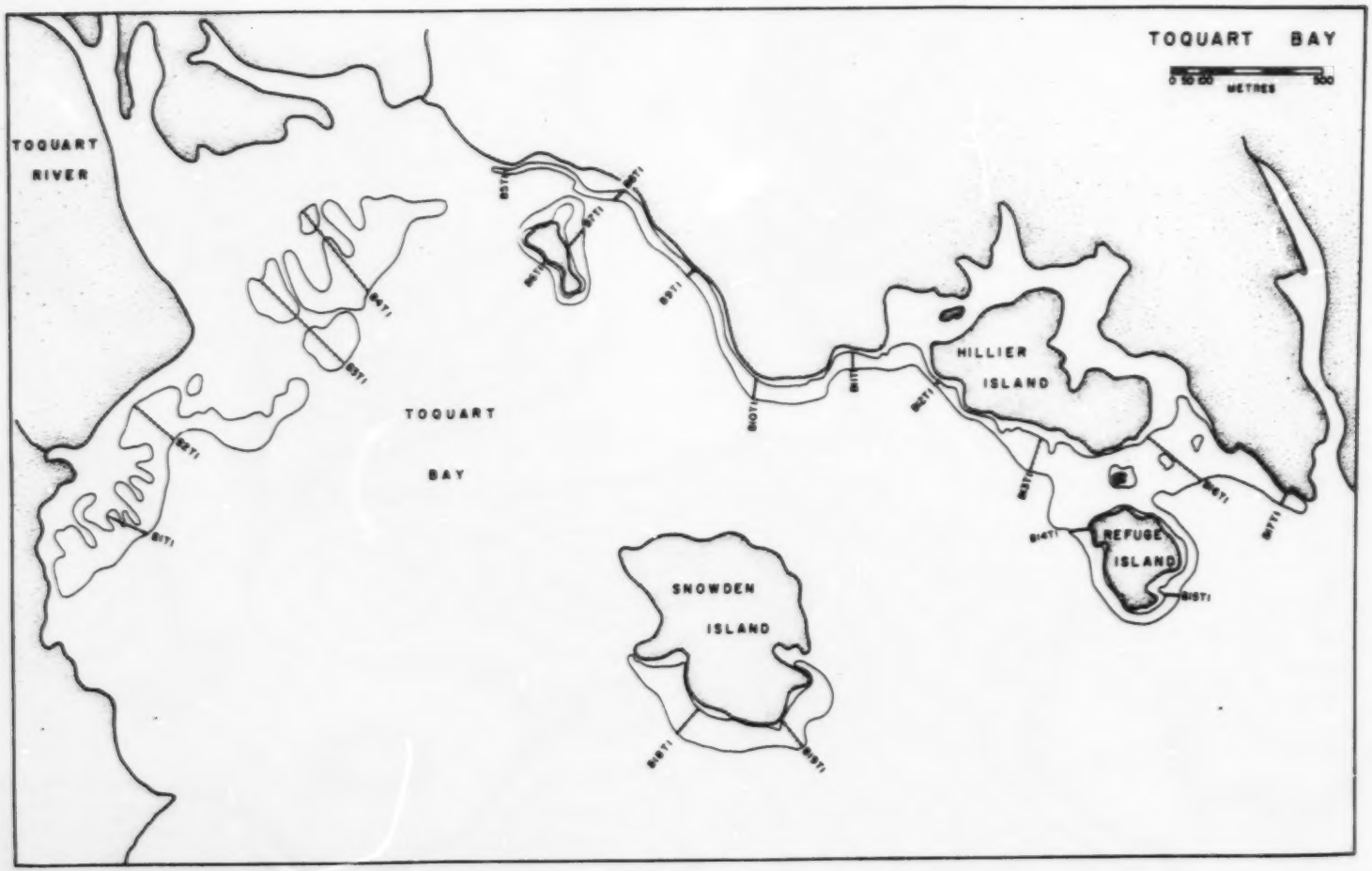

Figure 2. Herring spawn, surveyed by divers in 1982, in Toquart Bay, with transects and quadrat sample sites indicated.

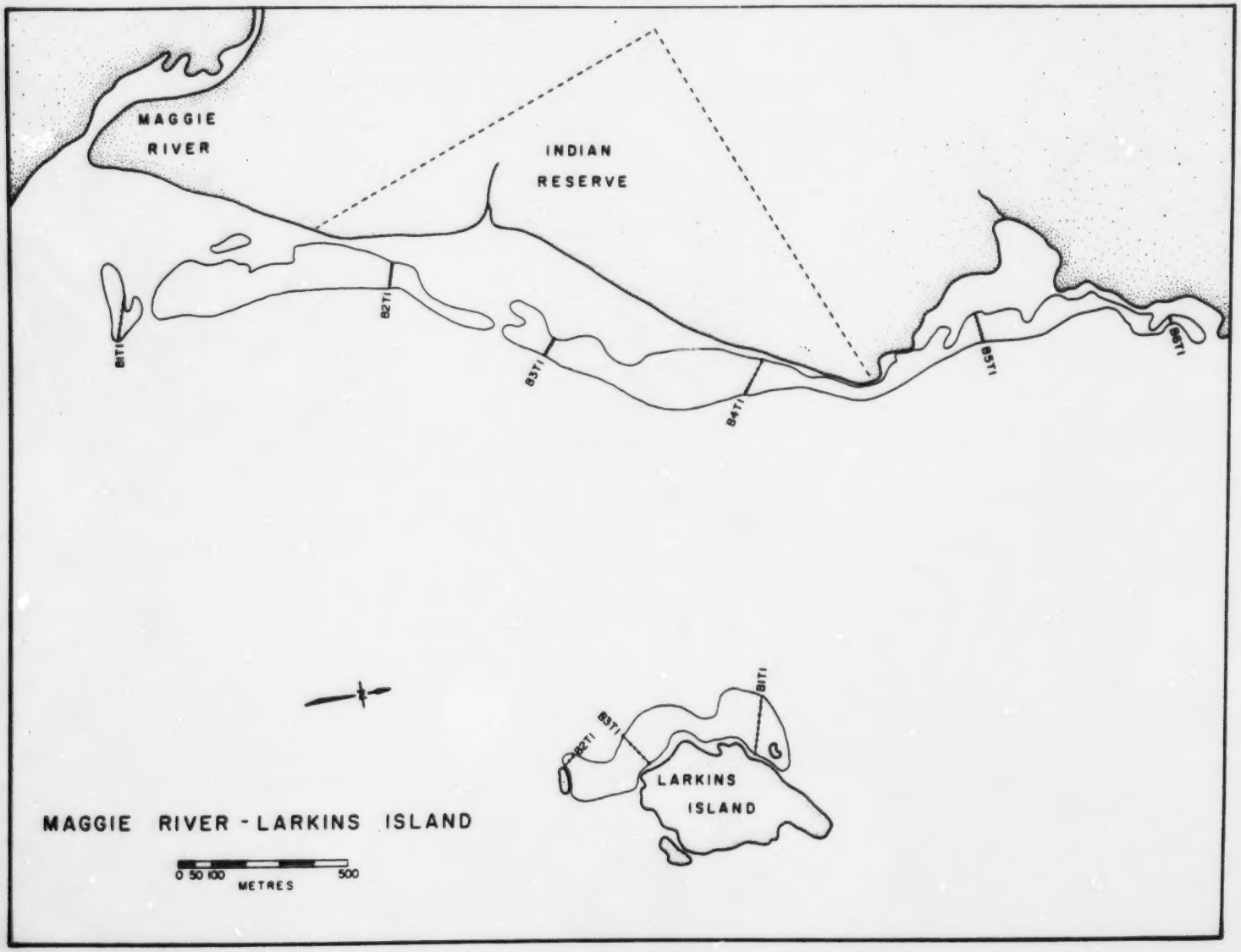

Figure 3. Herring spawn, surveyed by divers in 1982, at Maggie River and Larkins Island, with transects and quadrat sample sites indicated.

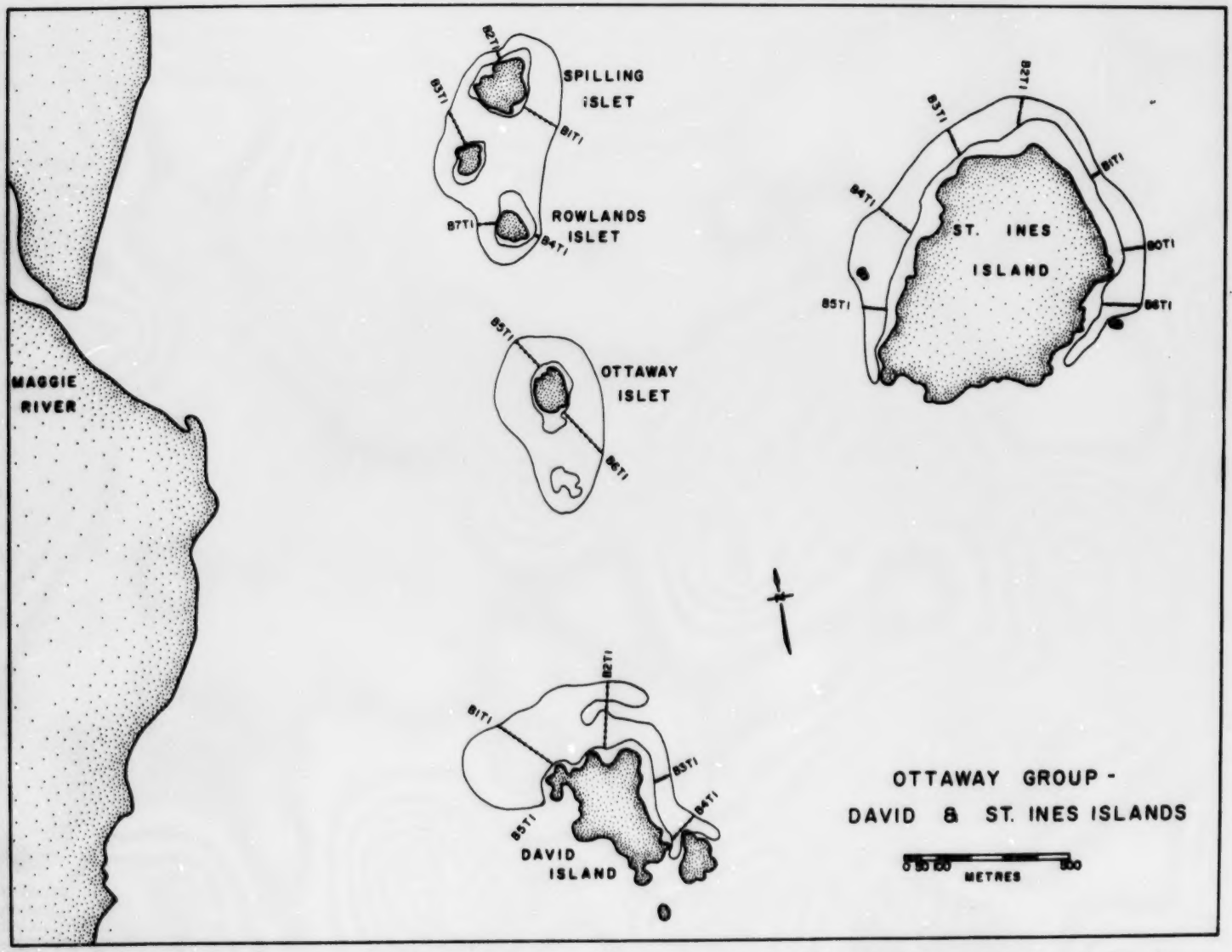

Figure 4. Herring spawn, surveyed by divers in 1982, around the Ottaway Group, David and St. Ines islands, with transects and quadrat sample sites indicated.

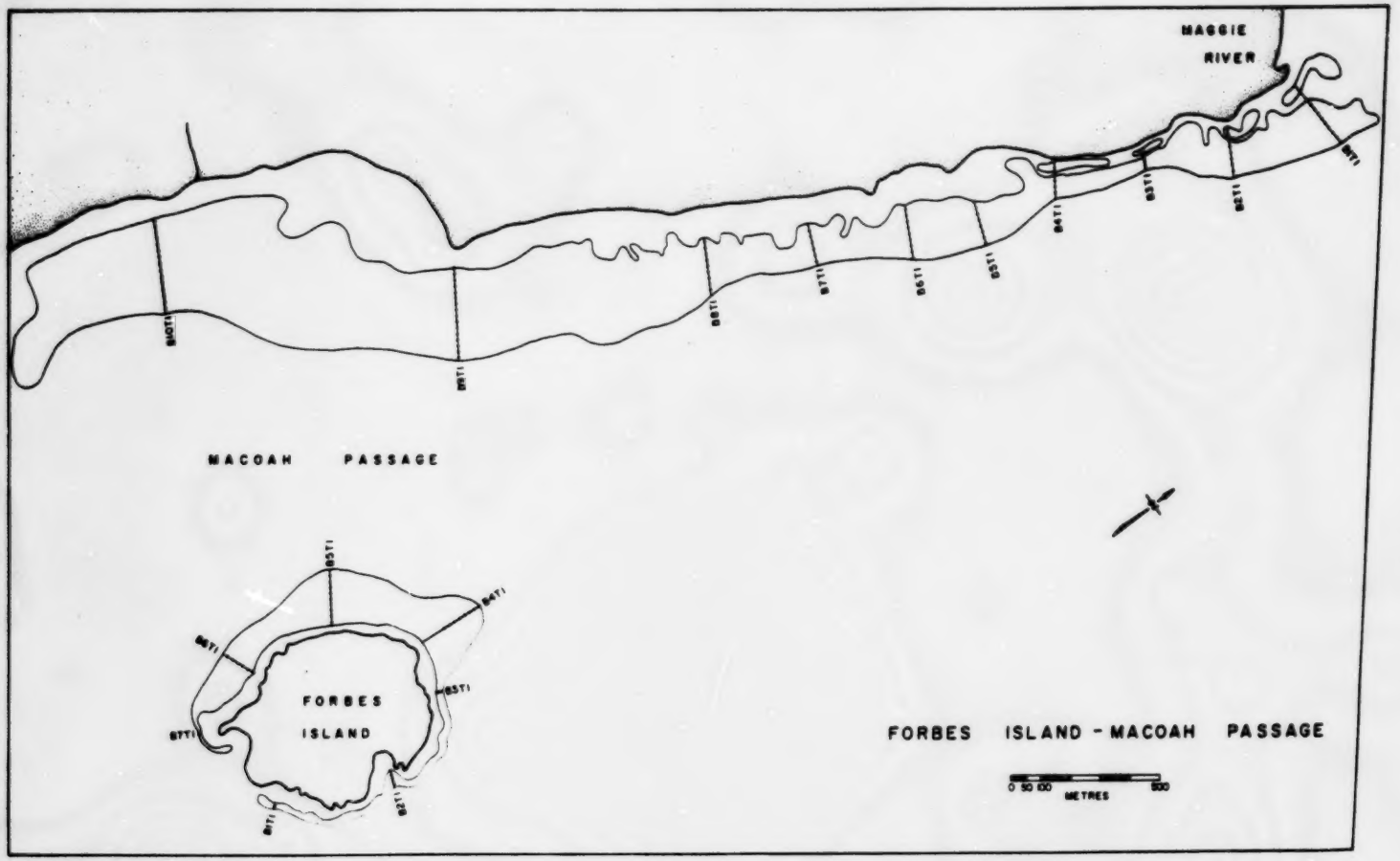

Figure 5. Herring spawn, surveyed by divers in 1982, around Forbes Island and in Macoah Passage, with transects and quadrat sample site indicated.

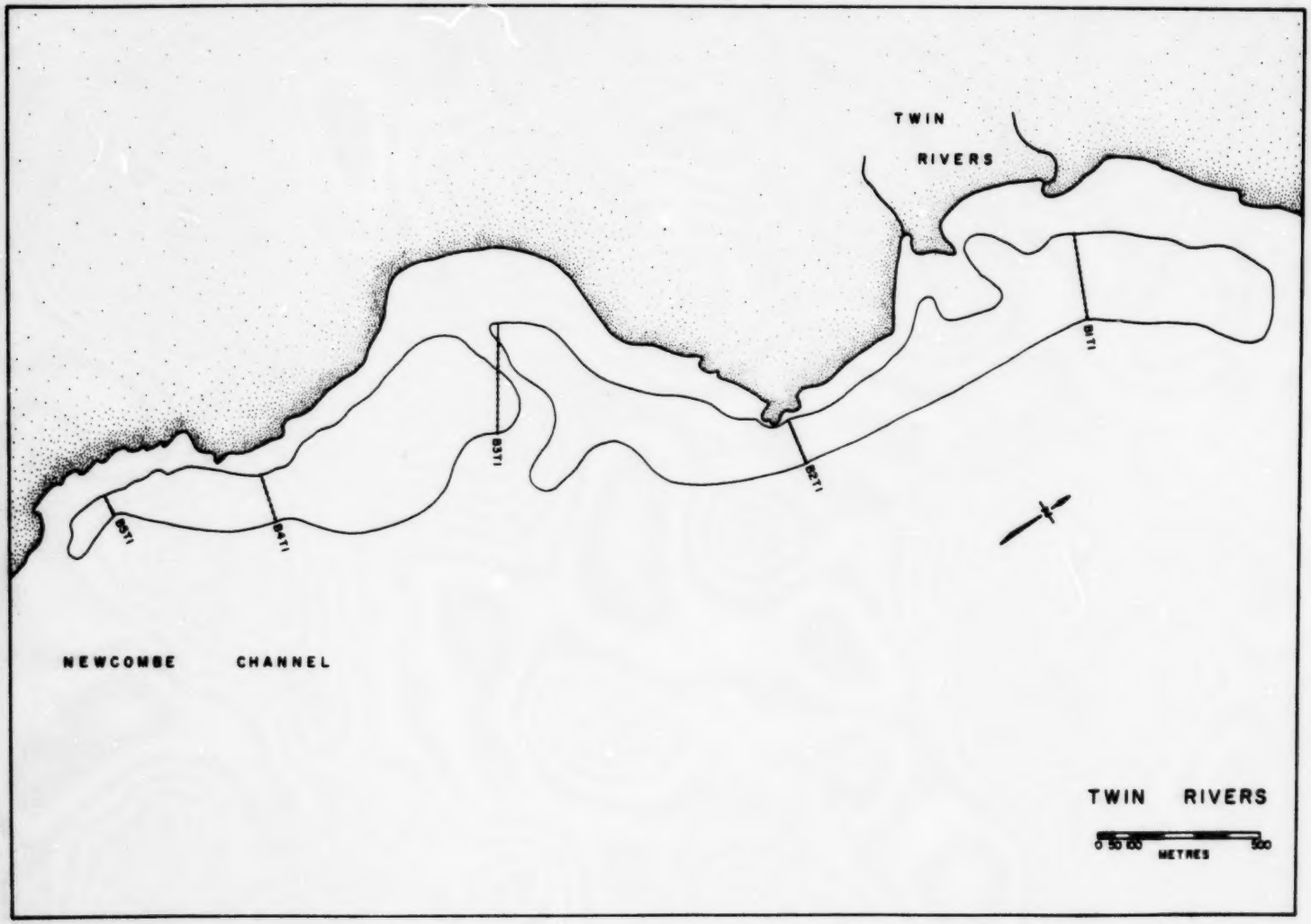

Figure 6. Herring spawn, surveyed by divers in 1982, at Twin Rivers, with transects and quadrat sample sites indicated.

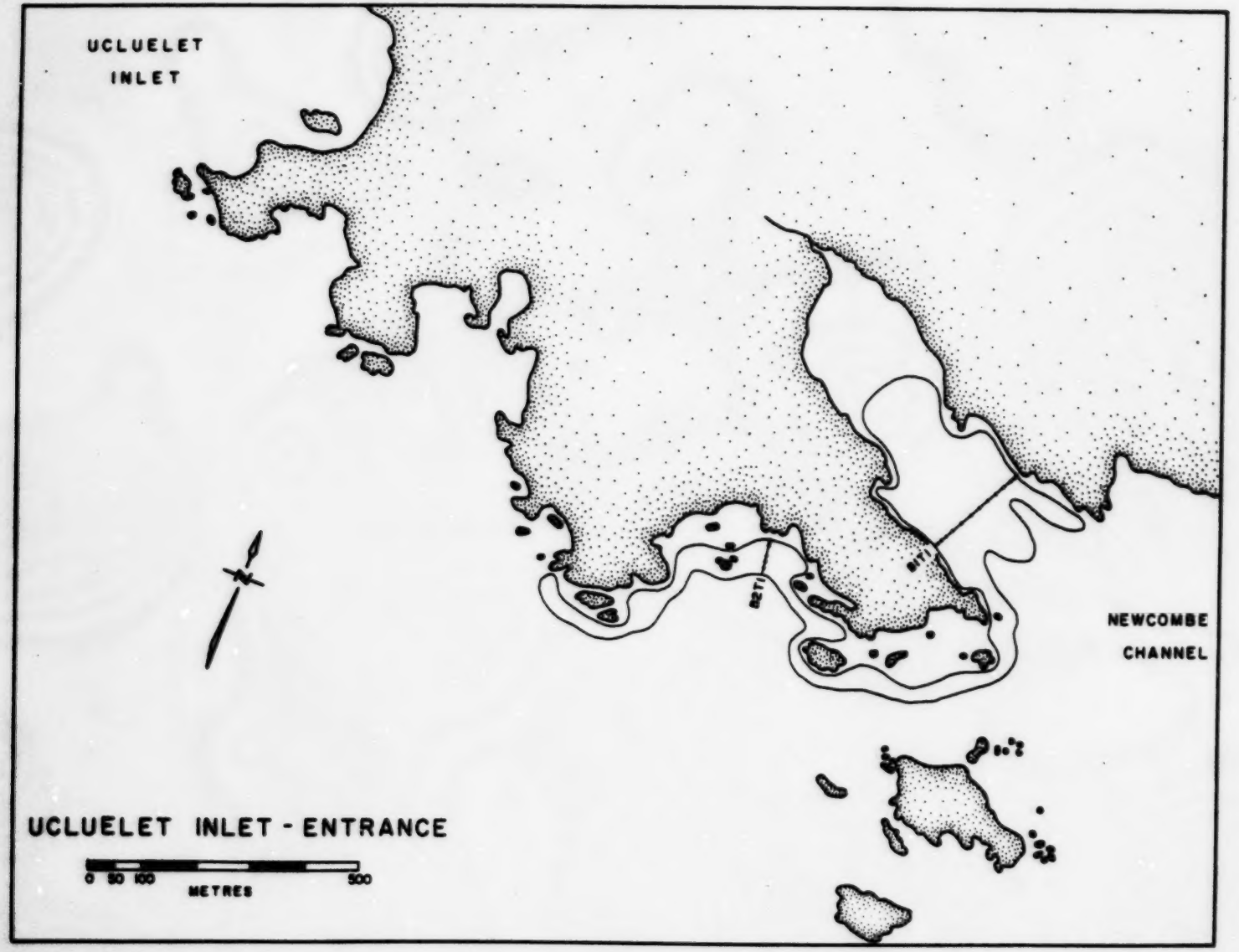

Figure 7. Herring spawn, surveyed by divers in 1982, at the entrance to Ucluelet Inlet, with transects and quadrat sample sites indicated.

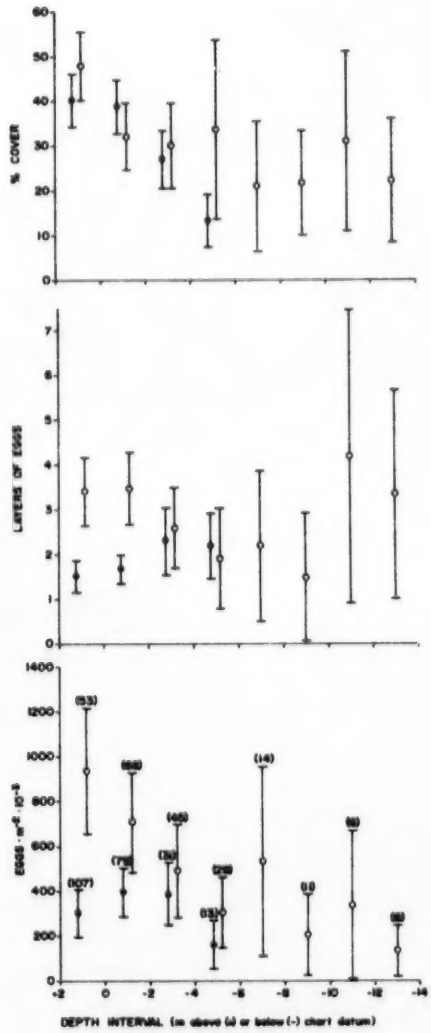

Figure 8. Average percent cover of vegetation, layers of eggs, and egg density (±2 SE) by 2 m depth interval for "Vancouver Island shoreline" spawns (closed circles) and "islands" spawns (open circles).

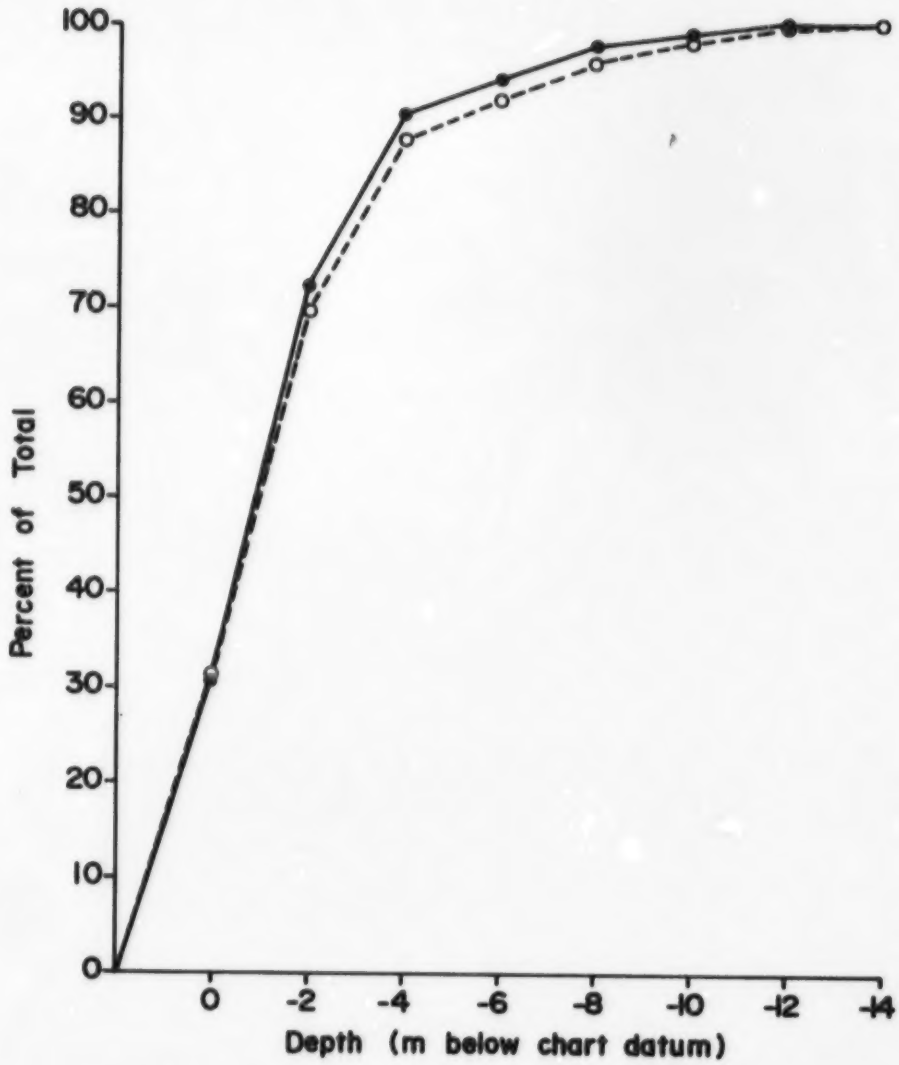

Figure 9. Distribution of spawn area (open circles) and number of eggs (closed circles) by depth.